

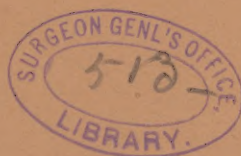
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A Study of the Soil in Relation
to Health and Disease.

BY GEORGE M. KOBER, M. D.,
OF FORT BIDWELL, CALIFORNIA.

presented by the author

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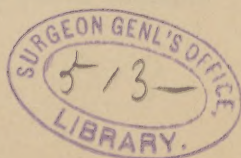


A STUDY OF THE SOIL IN RELATION TO HEALTH AND DISEASE.

BY GEO. M. KOBER, M. D.,
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The health of a locality is intimately connected with the character of the soil on which our habitations are built. This was recognized by the father of medicine, Hippocrates, who pointed out the relations of soil to certain fevers and their general effects on the constitution of man; and we know that over 2400 years ago attempts were made to drain the Pontine marshes and those of the Velubrum. All these efforts were based upon empirical knowledge; and although Lancise and Moscati, over one hundred years ago, made a microscopical examination of soil and the air condensed in rice-fields with a view of demonstrating the nature of malaria, it remained for Pettenkoffer to formulate exact methods, by which investigations of the soil, ground-air, and the ground-water and its fluctuations might be carried on, and their relations to health and disease—especially the infectious diseases—be explained. It is hoped that this arti-



cle may stimulate contributions to the geographical history of diseases in this country.

1. *Nature and Composition of Soil.*—By the term “soil,” we mean here the upper or superficial portion of the earth’s crust, which directly or indirectly supports animal and vegetable life, and which is therefore capable of affecting health by one or more of its properties.

All soils are composed of mineral, vegetable, and sometimes animal substances; and the character is largely influenced by the relative proportion of the different constituents, the dimensions of the fragments and the degree of their consolidation.

The mineral constituents of the soil may be derived from primitive rocks (granite, basalt, trachyte or porphyry), and stratified rocks like limestone, sandstone, slate and clay. Originally, they were all composed of sand and clay, and these constituents either occur alone or are intermingled in various proportions. The fine particles of soil are simply disintegrated rock, the result of the elements, and as the soil sustains vegetation, it is perfectly natural that it should also contain vegetable matter. Forests have been buried and again elevated, constituting *deposits*; *vegetable debris* is derived from plants, and is known as peat, humus, etc. In some places, especially in the sandy plains, near foot hills, the rain washes down finely-powdered debris and is filtered as it passes through the soil, so that each grain of sand may be *encrusted* with a film of vegetable matter.

The remains of animals are found in all but the primitive rocks; and whilst the animal constituents have generally disappeared, yet occasionally they have been distinctly traced even in the tertiary strata. On the surface, there is perhaps no soil which does not contain some animal matter.

These accumulations of rocks and soil form layers of various depths on the earth’s surface. In some localities, the impermeable strata crop out on the surface, whilst elsewhere they may be buried with loosely-consolidated material for a distance of a hundred feet or more—a matter of

importance in the question of wells, springs and ground air.

Comparatively speaking, even the hard rocks—granites and metaphoric rocks—cannot be considered impermeable; and between these, the dense rocks, the softer rocks and the loose soils covering them, we find, of course, different degrees of porosity and permeability. Delesse (*Bulletin Société Géol. de France*, 1861–1862, p. 64,) has shown that solid rocks may absorb water in the following amounts:

Granite	=0.06 per cent. to 0.12 per cent. of its weight.		
Slate	=0.19 per cent.	"	"
Sandstone	=0.66 per cent. to 13.15 per cent.	"	"
Basalt	=3.03 per cent.	"	"
Oolite	=3.29 per cent.	"	"
Limestone	=9.67 per cent. to 21.10 per cent.	"	"
Chalkstone	=24.1 per cent.	"	"

Since the water could only have entered the interstices before occupied by air, the figures demonstrate the relative porosity of these rocks. If, however, we apply the same test to weathered fragments or the disintegrated rocks, we find that whilst a solid piece of granite could only absorb 0.06 per cent. of its weight of water, granite, in the form of a powder, can take up 27 per cent. of its weight of water. Of the different kinds of soil which interest us most, the fine agricultural soils have the greatest number of pores, and gravel and sand the least number. The total number of pores varies in different soils, as follows: (Wolff, Flügge and Erismann.)

In fine garden soil,	64	per cent. of the total volume.		
In black sandy clay soil,	56.08	per cent.	"	"
In fine sandy clayey soil,	55.3	per cent.	"	"
In very clayey soil,	46	per cent.	"	"
In sandy soil,	35.5	per cent.	"	"
In sandy clay,	32.7	per cent.	"	"
In average fine gravel,	35.3	per cent.	"	"
In coarser gravel,	35.24	per cent.	"	"

2. *Ground Air*.—The interstices and pores of the soil are necessarily occupied by air, if not by water. This air is called ground-air, and although connected and interchangeable with the atmosphere, differs in this, that it contains

less oxygen and more carbonic acid. Oxygen is present to the extent of 15-20 per cent. of its volume, whilst carbon dioxide may be present in from 1 to 25 volumes per 1,000 and more. This is due to the chemical changes which take place in the soil, in which oxygen is consumed and CO_2 is evolved. Apart from this, we find ammonia derived from decomposition in the soil or imbibed from the atmosphere, the amount has been estimated from 0.0089 to 1.20 mgrm. per cubicmeter. Carburetted hydrogen and hydrogen sulphide have also been found, and even coal gas, which had escaped from defective pipes.

Dr. Nichols made an interesting series of experiments on the ground-air in the back bay lands of Boston. In his first experiments the air was drawn from $3\frac{3}{4}$ to $5\frac{1}{2}$ feet; there was no hydrogen sulphide and only a little ammonia; the CO_2 was from 1.49 to 2.26 volumes per 1,000, and varied inversely as the height of the ground-water, which was very near the surface. This relation was not constant at a depth of 6-10 feet. These observations and those of Fodor, Fleck and others, indicate that at a depth of thirteen feet, the air of the soil contains enough carbonic acid to extinguish a light, and certainly would be irrespirable. When we consider the depth of some of our cellars, and the fact that cellar-air often enters the house, we see at once a good reason for cementing our basements; but apart from this, ground-air may also harbor micro-organisms and disease-germs, which have been liberated from dry or pulverized soil, adding additional elements of danger which will be referred to later.

The composition of ground-air is of special importance, because it is in continual movement and connected with the atmosphere, by which interchange of gases can take place and thus affect the air of our habitations. The movements of ground-air have been demonstrated by manometres, and are influenced by the diurnal variation of the temperature of the soil, the rain-fall, and the rise and fall of the ground-water. As the ground-water rises, it displaces

the air from the soil; when the water sinks, air enters to occupy its place.

Fodor considers these factors, as well as alterations in barometrical pressure, together with the action of winds forcing air into the strata, all more or less essential in the movements of ground-air; it must also be apparent that loose porous soils offer the least resistance to the movements of ground-air. Apart from this, other local conditions play an important rôle, especially when the soil is covered with a house and the building heated with a furnace placed in a basement not cemented; in such a case, the objectionable ground-air may be drawn from great depths. Indeed, it has been shown that coal gas escaping from pipes and prevented from exuding by frozen earth on the surface passed sideways for some distance into houses. The air of cess-pools and defective sewer-drains have likewise found their way into dwellings, and the examination of drains alone often fails to detect the cause. Houses erected over "made soil," usually formed of house refuse and dry rubbish, are notoriously unhealthy and justly attributable to the constant ascent of impure air from the impure soil below into the warm rooms acting as aspirators above.

3. *Ground-Water*.—Water is one of the constituents of soil; for it is almost invariably present in the form of moisture and ground-water. When the soil is simply moist, we know that air and water are both present; but when all the interstices are filled with water, we have liquid mud, and have reached what Pettenkoffer defined as ground-water. The moisture of soil depends on its capacity to absorb and hold water, and on the supply of water in the soil either from rain, irrigation or ground-water. Meister gives the following table, showing the capacity of different soils for absorbing water:

Sandy soil	has a capacity of	45.4	vol.	per cent.
Quartz sand soil	" "	46.4	"	"
Chalkey soil	" "	49.5	"	"
Blue-clay soil	" "	50.5	"	"
Gypsum soil	" "	52.4	"	"

Limestone soil	has a capacity of	54.9 vol. per cent.		
Clay soil	" "	60.1	" "	" "
Peat soil	" "	63.7	" "	" "
Agricultural earth	" "	69.0	" "	" "
Humus soil	" "	70.3	" "	" "

Apart from the size of the fragments and the porosity of the individual particles composing it, the presence of organic matter vastly increases the absorbing and retaining powers of the soil. The chemical qualities of the soil likewise influence these properties. This is shown by the difference in quartz and clay soils, the grains of which have the same dimensions, but the former only absorb 3.66 vol. per cent., against 31.05 vol. per cent. of the latter. Whilst no soil is absolutely impermeable to water, for practical purposes they may be divided into *permeable* and *impermeable* soils. The former include chalk, sand, sandstone and vegetable soils; the latter, unweathered granite, trap, porphyry, gneiss and feldspathic rocks generally, also clay, slate, dense clays, hard oolite, hard limestone, etc.

The amount of rain which may pass into any given soil is of course influenced by the declivity and inclination of the soil, by the amount of evaporation, which is always greater in summer and during hot winds, and by the rapidity of the rainfall itself, which may be pouring down faster than the soil can absorb. Parkes estimates that on an average about 25 per cent. of the rain penetrates into the sand rock, 42 per cent. into the chalk, and from 60–96 per cent. into loose sand formations. The remainder evaporates or runs off the surface by natural drainage. It will be readily understood that by capillary attraction the upper layer of the soil may be kept moist from the subterranean water, even though evaporation is constantly going on at the surface; and this process is important from a hygienic point of view, because it attracts the moisture from deeper layers and may thus carry micro-organisms to the surface, which, if the evaporation goes on to the extent of dryness, may be liberated from the pulverized soil and carried with the dust into the air.

All the water from the surface, by reason of its gravity,

sinks and continues to do so until it reaches a point where all the interstices are filled with water, and here joins the subterranean water-courses. This may be at variable depths in different soils; sometimes it is only two or three feet from the surface, and it may be several hundred feet, depending largely upon the elevation above the surrounding country, the depth of the impermeable stratum, or "hard-pan," and the care with which the underground-water flows towards its natural outlets. It is not necessarily a horizontal underground sheet of water, for some impermeable stratum may crop out, opposing its further movements, and convey it in the form of springs to the surface. In low plains and valleys, the underground-water is generally not far from the surface. The movements of this water are constant in the direction of its natural outlets, which are springs, water-courses and the sea. The rate of this flow is influenced by the compactness, porosity and inclination of the soil, whilst the roots of trees naturally also lessen the movement.

According to Hess, the rate of movement of this ground-water is from forty to one hundred feet a day. Soyka determined a movement of 160 to 6,000 feet a day. In Munich, Pettenkoffer estimates its rate at fifteen feet daily. Fodor gives the mean rate at Buda-Pesth at 174 feet, with a maximum of 216 feet in twenty-four hours—calculated by the rise of the wells following a rise of the Danube.

The *level* of the ground-water is also constantly changing. This has already been referred to. It naturally rises after heavy rains; but the effects of rains are sometimes not perceptible until weeks or months after the fall; the rise and fall is sometimes quite rapid, depending on localities and seasons, its movement may be only a few inches either way; but in most places the limits between its highest and lowest levels in the year are several feet. In Munich, it is ten feet; in some parts of India, it is seventeen feet; in this Valley, it is fourteen feet.

There is generally a periodic rise, commencing in the fall of the year, and a corresponding depression in the spring, which has been attributed to the increased percolation of the

rainfall in the colder months and the greater evaporation in summer. The level of ground-water is also influenced by the pressure of water from the rivers or the sea, geological obstructions to its outfall, etc. When these obstructions are very great, the ground-water, stagnates and we have our marshes, and swamps, and tule lakes; these, when inland, are entirely due to the fact that the subsoil-water is held up by impermeable strata, and the water has no outlet except by evaporation.

4. *Absorption of Heat and Temperature of the Soil.*—The temperature of the upper layers of soil depends largely upon its exposure to the sun; but it is well known that the heat is absorbed in different amounts by different soils equally shielded or unshielded by vegetation, and that it depends largely upon the color of the soil. Dark soils absorb more heat than light-colored soils, and the dimensions of the grains and their chemical constitution also influence this property. The absorbing and retaining powers are not necessarily equal, and are greatly influenced by the degree of moisture; damp soils absorb heat more slowly, but they also cool more slowly than dry soil.

The following table by Schubler shows the capacity of different soils of absorbing and retaining heat—100 being assumed as the standard:

Sand with some lime,	100.0	Clayey earth,	68.4
Pure sand,	95.6	Pure clay,	66.7
Light clay,	76.9	Fine chalk,	61.8
Gypsum,	72.2	Humus,	49.0
Heavy clay,	71.1		

It will be seen, therefore, that sandy soils are warmer, and clayey soils are not only damp but colder.

The degree of temperature depends entirely upon the intensity of the sun's rays and differs in different latitudes and climates; but everywhere the rays of the sun produce two currents of heat in the soil. One wave is diurnal, the heat passing down in temperate climates to about four feet during the day, and receding during the night; the depth naturally varies with the season and the nature of the soil.

The other wave is annual, and in temperate climates the wave of summer heat reaches from fifty to one hundred feet.

The line of uniform annual temperature, according to Forbes, is from fifty-seven to ninety-nine feet below the surface.

5. *Soil Pollution*.—By soil pollution, we mean the presence of various impurities of vegetable or animal origin, which have either been washed from the surface into the soil or are derived from defective drains, sewers, cess-pools, privies, slaughter-houses, glue and soap factories, etc. Impurities, as already indicated, are also naturally present in alluvial and marshy soils. The impurities may be solid, soluble, and suspended or organized. Solid particles may be washed down as far as the pores of the soil will admit of their penetration and thence lodge, to be acted upon by the processes of disintegration.

Of the *soluble organic matter* likely to be present in soil pollution, whether from leaking cess-pools, sewers, drains or surface-pollution, we find soluble albuminoids, urea, ammonia and lime phosphate. The nitrates, nitrites and chlorides are generally not absorbed by the soil.

The suspended matter, whether living or dead, is held by the constituents of the soil, just as they would be arrested in a filter; it is for this reason that the surface of even virgin soil contains a large proportion of organic matter constituting the rich loams of our country. Indeed, this accumulation may be so great, that all the pores of the surface of the soil are filled with debris and the filter is clogged, in which case the water cannot penetrate and runs off; but if there is a dead level or a depression, it naturally stagnates and forms ponds or swamps.

The extent to which soil pollution can take place depends largely upon the porosity of the soil; and whilst it is generally considered that loose porous soils are healthy because they are dry, we may justly add, provided no soil pollution has taken place.

This I can best illustrate by the medical history of a

family which had more sickness, especially the so-called filth diseases, than any other family in my town. The inhabitants of a new house were well-to-do, intelligent and cleanly; the well was close to the house and the privy at least 150 feet from the well. It was impossible to connect the occurrence of typhoid fever and diphtheria in this family with a previous case; but I was informed that the building site, a dry gravelly spot, was formerly used for a cow corral and hog pen. In view of all the circumstances, there was nothing improbable in the assumption that the animal refuse matter permeated the soil for a considerable depth and furnished suitable food for disease-germs, which, with the recession of the sub-soil water, were stimulated into activity, and finally percolated into the well, or gained access into the air of the rooms by the movements of the ground-air in the manner already referred to.

But, not to digress too much, let us study the *efforts of nature to eliminate impurities in polluted soil*. It is very certain that the organic matter does not remain unchanged. In porous soils, where the air can gain free access, oxidation takes place. The carbon is converted into carbonic acid and the nitrogen into nitrates and nitrites; and this explains the excess of carbonic acid even in virgin soil. A certain degree of moisture is, however, necessary; for it has been shown that if only 1 or 2 per cent. of moisture is present, no carbonic acid is generated. Warmth is also essential; the production of CO_2 of nitrates and nitrites goes on quite rapidly in warm soils, but is retarded in cool weather, and ceases almost completely at the freezing point. Last, but not least, the presence of bacteria is absolutely essential in the decomposition of organic matter. Pasteur has shown that in soil in which these organisms have been destroyed (sterilized), no nitrification takes place, even if all the other conditions are present. From these and numerous other experiments, it has been concluded that the oxidation of organic matter in the soil is not a purely chemical process, but is brought about with the aid of micro-organisms, which

feed upon it, and as they multiply, they split up the organic matter into simpler compounds.

The rapidity of oxidation, apart from the conditions mentioned, is also influenced by the chemical constitution of the soil; a certain degree of alkalinity is absolutely essential. In fact, nitrification ceases when the nitric acid fails to find a suitable base for its combination.

It has been shown that next to lime, the presence of soda, potassa and ammonia carbonate hastens nitrification.

It will be seen that this beautiful process of nature is evidently intended for the purification and utilization of effete matter, and thus not only interests the agriculturist, but also the sanitarian. Nature is ever kind and indulgent, and it is only when we impose upon her, or expect too much from her forces, that we are disappointed.

The capacity for self-purification of the soil is naturally limited. If the soil is charged with organic matter to a greater extent than it is capable of oxidizing, by reason of its physical and chemical constitution, an accumulation takes place, which naturally affects the permeability and healthfulness of the soil; for in place of oxidation, we will have deoxidation or putrefaction, all because the pores of the soil are closed and oxygen cannot enter. In such an event, we get nitrous acid and ammonia; the sulphates are reduced to sulphides, and we find in consequence hydrogen sulphide, ammonium and ferrum sulphides. If much iron is present, free hydrogen sulphide is not produced, no matter how strong the organic pollution may have been; but if the soil is deficient in iron and rich in gypsum, free sulphuretted hydrogen is evolved. Even these reduction processes are not purely chemical, but are initiated by the bacteria of putrefaction.

The principal sources of soil-pollution may be summed up as follows: Human and animal refuse, fæces and urine, the dead bodies of animals and man, vegetable debris, refuse of industrial pursuits, and deposits from floods. These are especially objectionable if the soil in the particular local-

ity is already damp and likely to keep the fresh sediment also damp. If, on the other hand, the mud has a chance to dry, oxidation will speedily destroy the rich quantities of organic matter contained therein.

6. *Micro-Organisms in the Soil*.—Reference has already been made to the presence of microbes in the soil. They are quite numerous, but decrease in number with the depth of the soil.

Beumer (*Deutsche Med. Wochenschrift*, 1888, No. 27,) found in—

1 c. c. of sandy loam at a depth of 10 ft.,	44-45 million germs.
" " " " 13 ft.,	4-10 " "
" " " " 16 ft.,	5-8 " "
" " " " 20 ft.,	6-5 " "
" " marls " " 13 ft.,	1½ " "
" " " " 16 ft.,	1½ " "
" marls " " 13 ft.,	750,000 germs.
" " " " 16 ft.,	380,000 "
" cemetery earth, sandy, "	4 ft., 1,150,000 "
" " humus, "	6 ft., 430,000 "
" yellow clay, "	6 ft., 260,000 "

The investigations of Pagliani, Maggiori and Fratrini at Milan, in 1887, quoted by Uffemann, also show that the upper layers of the soil contain the greatest number of micro-organisms; that they decrease with the depth; that they are more numerous in manured and cultivated than in virgin soils, and that the soils of forests contain the least number of germs.

The micro-organisms of the soil include fungi, ferment bodies and bacteria—the latter preponderate in the upper layer of soil.

Of the *fungi* which have been isolated, there are, according to Adametz, the following varieties: *Penicil. glaucum*, *mucor mucedo*, *M. racemosus*, *M. stolonifer*, *Asper. glaucus*, *Oidium aurantiacum*, *O. lactis* and *clostridium butyricum*.

Of the *ferment bodies*, the *saccharomycetes glutines*, *cerevisiæ*, and *rosaceus* and the *Monil. cand.* have been demonstrated.

Of the *bacteria*, there have been found the *micrococcus*

candidus, luteus, aurantiacus, versicolor, cinnabareus, roseus, diplococcus luteus, bacterium lineola, termo, subtilis, mycoides, viridis, liquifaciens and non-liquifaciens; B. allus, rubescens, prodigiosus, proteus vulgaris, the bacillus butyricus, vibrio rugula and many others.

Of the *pathogenic bacteria*, the following have so far been discovered in the soil: The bacillus of *tetanus* by Nicolaier in garden earth, but it is not found in all soils. Bonome claims to have found this bacillus also in mortar, in which case it was probably derived from the soil. The bacillus of *anthrax* was found by Frank in the clay of a stable formerly kept for the storage of hides. The bacillus of *malignant œdema* was found by Koch and others, and the bacillus typhosus by Tryde in the soil beneath a barracks. Klebs and Tommasi-Crudeli described a bacillus found by them in the water and soil of the Roman Campagna, which they regarded as the microbe concerned in the causation of malarial fevers; but it is now held that Laveran's *plasmodium malarix* (a species of protozoa) is the essential agent of the disease.

The investigations, so far, appear to indicate that pathogenic microbes are not very frequent in the soil. On the other hand, it must be remembered that the methods of bacteriology are far from perfect, and that much more may be accomplished in future.

The development of the micro-organisms naturally depends upon a suitable food, moisture and a certain degree of warmth. This pabulum they find in the organic matter of the soil, which not only contains carbon and nitrogen, but also the salts requisite for their growth. Investigation has shown that when the soil contains less than 4 per cent. of moisture and possesses a lower temperature than 32°, their development ceases, and that they luxuriate best in a warm porous soil rich in organic matter, moist but not wet, and they nearly all require a sufficient amount of oxygen.

In order to determine the depth at which pathogenic bacteria may still grow, Fränkel made a series of experi-

ments with anthrax, typhoid and cholera bacilli, and found that the multiplication of anthrax bacilli is retarded at a depth of seven feet, and completely arrested at ten feet; the bacilli of cholera continued to grow at a depth of ten feet during the months of August, September, and October, but not during the other months; at a depth of five feet, however, proliferation continued during the entire year. The typhoid germs ceased to grow, at a depth of ten feet, only during the months of April, May, and June; during all other months of the year, they multiplied vigorously.

Whilst the number of micro-organisms in the soil is really enormous, by far the majority are harmless, and are the scavengers of nature and ever active in the nitrification, fermentation, and putrefaction, which split up the organic matter into substances best suited for assimilation by vegetable roots. It is perfectly conceivable, that disease germs may be washed from the air or gain access to the soil by clinging to organic matter of every description, and thus find their way into wells and springs, or they may reach the surface by the ascending currents of the ground-air, and be again liberated from the pulverized soil. Pasteur has pointed out how anthrax bacilli have been turned up by earth-worms, and it is scarcely necessary to indicate the many ways by which man himself, in excavations and agricultural pursuits, may be instrumental in bringing the microbes to the surface. The occurrence of malarial fevers, after turning up the sod of virgin soil, can rationally be explained in this way.

Summary.—From the foregoing, it is evident that the soil may affect the health of those immediately residing thereon by the ground-air, dampness, soil pollution, and disease-germs.

We have seen that the ground-air is in constant motion, interchangeable with the atmosphere and the air of our houses—that it contains impurities, viz: an excess of carbonic acid, sometimes ammonia, and occasionally hydrogen sulphide, and coal gas. If these gases pass directly into the

atmosphere, no harm can result; if they pass into our cellars or basements, the air of our homes will be vitiated. The extent to which this may take place we cannot here discuss. The possibility of disease germs entering the outer air and the air of habitations through the movements of the ground-air has also been pointed out.

In reference to the *moisture of soils*, we have learned that the degree of moisture naturally affects the humidity of the atmosphere; it is for this reason that the air of meadows and valleys is, generally speaking, damper than the air over sandy plains or agricultural soils. The humidity of the soil is of the greatest importance in the disintegration of organic matter, and may determine, in one instance, oxidation—in another, reduction or putrefaction. The degree of moisture may be just sufficient to promote or arrest the development of certain disease germs. The rain which percolates the soil may carry these germs into the ground-water and thus contaminate the drinking water, provided, of course, they have not previously been arrested by the filtering and absorbing properties of the soil.

In regard to the *ground-water*, we have seen that its rise and fall influences the amount of moisture in the upper layers; if it rises to within a few feet of the surface, the dampness extends by capillary attraction to the atmosphere, and by evaporation cools the air; and if, perchance, a dwelling should be located on a damp soil, this dampness will extend to the house, and may cause a damp and chilly air within.

The movements of the ground-water also cause corresponding movements of the ground-air; a sudden and considerable rise of the ground-water forces the ground-air before it and out of the soil. This may result in an upward displacement, not only of noxious gases and effluvia, but also of micro-organisms. I have had repeated opportunities to observe the disagreeable effluvia, after a sharp rise of the stream which drains this town. A gradual rise accomplishes, of course, the same purpose. With a recession of

the ground-water, the air enters the deeper layers of the soil, and may stimulate into activity certain disease germs which remained dormant as long as they were submerged.

In reference to soil pollution, it is evident that even the manuring of cultivated fields may give rise to offensive effluvia; it is an open question whether such emanations can produce disease, or whether the presence of organic matter in the soil is ever itself the cause of disease. It is probable, however, that it simply furnishes a vehicle and suitable nutriment for disease germs, since we know that soil pollution plays an important rôle in the production of typhoid fever, malaria, diphtheria, dysentery, and other filth diseases.

We know that pathogenic germs may be conveyed from the soil directly and indirectly. The investigations of Bonome, Beumer, and others, have shown that contact of open wounds with certain soils has resulted in trismus and tetanus, and the same mode of infection is probable in malignant œdema, which is also caused by a specific germ. Generally speaking, however, disease germs first gain access into the *air* or *water*. It has been indicated how they may reach the air in the form of pulverized dust and be inhaled; other germs may reach the water-courses or percolate into wells and springs through the movements of ground-water.

We also know that cattle which have been grazing on grass and clover-fields, the soil of which has been infected by burial of dead animals from anthrax, have contracted the disease. This at least suggests the possibility that the germs of typhoid, dysentery, etc., may be conveyed from fields, through the medium of vegetables which are eaten raw, like lettuce, radishes, strawberries, etc. By examining these, after a heavy shower, and observing the spattered mud, we can readily appreciate how such a transmission is possible.

The Relations of Soils to Certain Diseases.—Whilst it will be impossible to consider here, in all its details, the influence of soil in the production of diseases, we shall enumer-

ate a few of the most prominent affections believed to be intimately connected with the constitution of certain soils:

(1) *Endemic Goitre and Cretinism*.—According to Bircher's investigations, these affections occur solely in localities where the soil and geological formations are composed of marine deposits of the Palaeozoic age—the trias and tertiary period. The eruptive formations, the crystallized rocks of the ancient formation, the sediments of tufa and chalk, as well as those of the quaternary period, and all sweet-water deposits, are believed to be free from the disease-producing agent, which Bircher believes to be the "navicula," a form of the algae, which occurs in the drinking water of these marine deposits.

Kratter, however, found that alpine cretinism was most prevalent in localities where the soil consisted of the debris of primitive rocks, and the springs had their origin in such formations that it was rarely seen in limestone regions, that it was not observed in altitudes above 3,400 feet, nor below those of a 1,000 feet, and that it was most frequent in altitudes between 1,400 and 2,300 feet.

It was formerly believed that these diseases were connected with limestone formations, but, in the mountains of Tyrol it occurs much oftener in slate districts, and the limestone regions of England and France afford comparatively few cases. Some authors attribute the cause to magnesian-limestone deposits, and Klebs disclaims the influence of soil formations on these affections altogether. The evidence is quite conflicting, but it is very certain that goitrous and cretinic districts exist, and there are numerous well-attested cases of healthy women living during their pregnancy in such districts, bringing forth cretinoid children, who, removing from such localities, propagate healthy children.—*[Down.]*

(2) *Malaria*.—It has not yet been definitely settled whether Klebs' bacillus or Laveran's plasmodium malarie is the etiological factor of malarial diseases. Both organisms are believed to have their habitat in malarial soils.

Whilst it is impossible to give the exact composition of the soil requisite for the development of malaria, we know that it requires a soil rich in organic matter—moist, but subject to periodical dryness. Such soils are principally found in valleys or on plains, with depressions favoring the stagnation of water and formation of marshes; also in localities subject to periodical overflows, especially near the sea-coast, where a mixture of sweet and salt water results in the so-called brackish water. Endemic malaria is not observed in dry, well-drained soils, especially when poor in organic matter. Another important factor is a certain degree of heat. Tommasi-Crudeli demonstrated that his bacillus only matured at a temperature of 36° and above; the inference is that soils possessing a lower temperature than 36° cannot produce the germs, and our knowledge of the geographical distribution of malaria confirms this. The disease is very infrequent in the northern part of the United States; it is a rarity in the Faroean Islands, and unknown further north, whilst it increases as we travel south, and amounts to almost a scourge in sub-tropical and tropical climates. As a periodical drying of the soil is one of the factors necessary for the diffusion of the malaria, it may be claimed that this process liberates the microbes, which are held down as long as the soil is moist. But this is not applicable in all cases, for we know that malarial intoxication often follows large excavating operations before the soil even had an opportunity of becoming pulverized.

The good effects of drainage in reducing malarial affections almost 75 per cent. have been demonstrated in Michigan, and similar results have been obtained in Italy, France, Algiers, England, and Germany.

The withdrawal of moisture, and consequent change of environments, evidently prevents the propagation of the germs, as the disappearance or diminution of the disease resulted from proper drainage.

(3) *Dysentery*.—Clinical experience points to the fact that dysentery is most prevalent in malarious regions. Wasser-

fuhr attributes the virus of dysentery to a moist, warm soil, charged with organic matter and polluted with animal excreta; he refers to a locality in Alsace used for an artillery drill-ground, which not only affords numerous cases of dysentery, but also of malarial fevers and intermittent neuralgia. The soil is peaty, resting on a layer of sand which is upheld by a deposit of dense clay. Prof. Virchow, however, tells us that dysentery occurs in localities which are quite free from malaria, as in certain parts of Egypt, where its prevalence is solely attributed to impure drinking water. It is quite probable that soil-pollution added to a malarious soil, especially in overcrowded camps, favors the development of the virus of dysentery, which finally enters the system in the form of amœbæ through contaminated drinking water.

(4) *Tuberculosis*.—The relations between dampness of soil and pulmonary consumption were first pointed out by Dr. Bowditch, of Boston, and Dr. Geo. Buchanan, of England, and the facts compel a fair investigation. Dr. Buchanan, in the Ninth Report of the Medical Officer of the Privy Council, London, 1867, also supplies ample statistical proof that consumption became less frequent in certain towns after they had been sewered and the soil consequently drained. In some towns, where the drainage was perfect, the deaths from phthisis were reduced by a third, or even by half.

	<i>Mortality from Consumption</i>		
	<i>Before Sewers.</i>	<i>After Sewers.</i>	<i>Decrease.</i>
Merthyr,	38.66	34.33	4.33
Bristol,	31.00	25.50	5.50
Leicester,	43.33	29.25	14.08
Cheltenham,	28.75	21.25	7.50
Cardiff,	34.75	28.66	6.09
Macclesfield,	51.50	35.60	15.90
Newport,	37.00	25.00	12.00
Warwick,	40.00	32.33	7.67
Banbury,	26.66	15.66	11.00
Salisbury,	44.33	22.66	21.67
Ely,	31.00	16.75	14.25
Worthing,	30.50	19.50	11.00
Rugby,	28.50	16.25	12.25

It is true that a reduction in mortality did not always follow the introduction of sewers, but in such instances it may be fairly assumed that the soil was previously quite dry, and could not be affected by increased drainage.

Uffelmann refers to a striking illustration of damp habitations as a predisposing cause to consumption. It is a prison near Vienna containing on an average 200 inmates. Every convict is examined before his transport, and if found affected with incipient phthisis, he is sent elsewhere. In spite of this precaution, the deaths number about fifty per annum, and the majority die from consumption. The prisoners are better fed in this institution than elsewhere, but the building rests on a damp, clayey soil, the walls are reeking with moisture, and the rooms smell musty.

The relation of dampness to consumption can only be explained on the ground that the bacilli of tuberculosis luxuriate best in such an atmosphere, which, on account of its humidity, very likely contains also much organic matter. Apart from this, a damp air naturally predisposes to catarrhal affections, and these, in turn, render the mucous membrane more vulnerable to the invasion of the tubercle bacilli.

(5) *Enteric Fever and Cholera*.—There is considerable difference of opinion on the influence of soil as a factor in the causation of these diseases. Prof. Pettenkoffer and his adherents believe that the soil is absolutely essential in the spread of these diseases; that the virus develops in the soil and is carried by emanations into the air, and that the rise and fall of the ground-water determines the frequency of these diseases. He holds that a fall of the subsoil water is followed by an increase, and a rise of this water by a decrease in the number of cases. The majority of sanitarians of the present day assume, however, that the virus of typhoid fever and cholera is reproduced in the body of those afflicted with the disease; that it requires no further elaboration or maturity; that this virus leaves the body in the excretions and is capable of proliferation wherever it finds

suitable environments; they look upon certain articles of food, as well as certain waters and soils, especially those contaminated with organic matter, as suitable media for the multiplication of these germs. According to this view, the soil is simply the medium for the propagation of these germs and their transference into the drinking water; and whilst the rise and fall of the ground-water doubtless facilitates their passage into springs and wells, it plays another rôle in so far as it affects the amount of air, heat and moisture requisite for the multiplication of these germs.

(6) *Cerebro-Spinal Meningitis*.—Clinical experience points to the fact that this disease occurs most frequently in damp and polluted localities. In the numerous epidemics which have been studied, the habitations were found almost invariably damp, the soil polluted, and in many instances the outbreak followed floods or inundations.

Sanitary Measures in Reference to Soil.—From the foregoing remarks, it is evident that the principal sources of danger from soil are *dampness* and *soil-pollution*.

The relations of dampness to the more important diseases like malaria, dysentery, consumption, etc., has been pointed out, and we might have included pneumonia, rheumatism, neuralgia, and many other diseases in which dampness constitutes a predisposing factor.

We have learned the necessity of excluding the ground-air from our houses by cementing the basements; and as the dampness of the soil not only affects the atmosphere, but, by capillary attraction, extends to our houses the necessity for rendering the walls damp-proof, by a course of slates imbedded in cement above the level of the ground, is obvious. These are matters more strictly belonging to the hygiene of habitations, and we will therefore consider the means at our command to render damp soils dry. The good effects of drainage have already been pointed out; this should be done wherever the moisture is excessive and another outlet for the water cannot be secured. In many localities surface-drainage appears to answer the purpose,

but sub-drainage is of the greatest value in influencing the height of ground-water, which is carried off when the water rises to the level of the drains. Some localities have been rendered more salubrious by planting trees, which absorb a great amount of moisture and give it off in evaporation.

It has been estimated that an oak tree evaporates $8\frac{1}{2}$ times the rainfall, and the eucalyptus absorbs and evaporates eleven times the rainfall over the area it covers. This tree has been extensively planted in malarious districts with the effect of diminishing malaria. It is quite possible that, apart from its value in diminishing the moisture of the soil, the ethereal oil of eucalyptus being a germicide, may exert its properties on the microbe of malaria; but, on the whole, there is nothing like perfect drainage, especially in marshy soils, for it has been shown that vegetation alone is insufficient to render the Campagna di Roma salubrious.

Measures looking to the prevention of soil-pollution consist in the proper care and disposal of refuse, more especially the animal excrementitious matter, and the construction of proper sewage systems. Apart from this, much may be done in communities by pavements, grading and seeding of the soil in public places.

The effects of floods may be mitigated at least by promptly cleaning out the wells and springs, and the removal of surface deposits as far as this is possible. Under no circumstances should the water in overflowed districts be allowed to stagnate.

Distribution and Comparative Healthfulness of American Soils.—The most widespread soils in the United States are sandy soils, clayey soils, and loams. The *sandy soils* consist of about 75 per cent. of quartz-sand, and are generally the healthiest on account of their warmth and dryness, provided, however, they have not been subjected to soil-pollution, and are not kept damp by an underlying layer of clay or other impermeable strata.

(2) The *clayey soils* contain 75 per cent. or more of clay, [alumina silicates], and are objectionable for building sites,

because they are usually cold, wet, and impermeable, unless the surface affords good drainage, or the site is sub-drained. The *loamy soils* are sub-divided into sandy or clayey loams, according as one or the other of these constituents predominates. The clayey loams should be avoided, and whilst clean dry sandy loams are usually healthful, they may, like the sandy soils, present similar objections.

In addition to the soils referred to, we find the following less frequent: The *stony* or *gravelly soils*, which are quite local in distribution, and generally very desirable for building sites, on account of their warmth and dryness. The *calcareous soils* are loams or sands impregnated with 5 to 50 per cent. of carbonate of lime, and occur only in limestone or marble districts. Apart from the hardness of the water, which in itself is not injurious, the soil is generally regarded as salubrious. *Magnesian soils* result from the disintegration of serpentines, talcose, or other magnesian rocks—they are porous soils, and usually healthy; the magnesian salts in the water supply are objectionable, but these soils are quite uncommon in this country. The *highly ferruginous soils* are very local, and overlie deposits of log iron ore. Malarial diseases have been attributed to their proximity, but Dr. Britton has heard no such complaints in this country. The *mud* and *peat soils* are confined to low grounds or mountain valleys, which afford no outlet for the surface water; they are essentially marsh soils, consisting of loams or clays saturated with water and charged with vegetable matter to the extent of 50 per cent. and over. Whilst peat soils are non-malarial, they should be avoided. The soils of *humus* and *mold* result from abundant vegetation in comparatively dry localities, and are the natural soil of forests and former prairies covered with grasses and herbs, and rarely extend beyond a foot in depth.

Soils are either *indigenous* or *transported*; in the latter instance, they have been brought by glacial action or the forces of water from other localities, and may have nothing in common with the underlying rocks.

The soils of *glacial drift* consist of deposits of clay, sand, gravel, and boulders, which have been brought from the north in icebergs during the glacial epoch; sometimes there are signs of stratification, but generally there is an absence of structure. The surface of glacial drifts is usually irregular and affords good drainage, but at times an excess of clay renders them less desirable for building sites unless properly drained. Along the southern margin of this drift, on the Atlantic Coast, the surface conformation of the "terminal moraine" is such as to favor the formation of swamps and stagnant ponds in hollows, often surrounded by much higher grounds, although many feet above tide-level. In such instances, proper drainage affords the only remedy.

The drifts in some localities present a well-marked stratified structure; this may have been the result of direct glacial action, but more often the clay, sand, and gravel, were deposited from the currents of water and lakes which accompanied the melting of the glaciers. When these drifts are mostly composed of sand and gravel, the soil, on account of its porosity, decline of surface, and freedom from organic matter, is very salubrious, but an excess of clay renders them suspicious. The so-called yellow drift is found extending in patches from the southern coast of New England over nearly the whole of Long Island; thence southerly, composing nearly all of the soils of Southern New Jersey, Delaware, Eastern Virginia, and in patches along the coast of Florida. Much of this territory is covered by pine forests, and the majority of our seashore and health resorts are situated in this belt, which owes its salubrity to the sandy and gravelly nature of the soil. These yellow drift deposits are believed to have been made before the glacial drifts, at a time when a large part of Eastern North America was still submerged.

Alluvial deposits are the result of the action of water in depositing the silt held in suspension, and when only slightly elevated above the level of the stream usually contain a dangerous amount of organic matter. River terraces

are produced by a stream cutting through such deposits to gain a lower level, and by these the ancient course of a stream may often be traced. Lake terraces generally indicate the former levels of the water; the highest benches are always preferable for building sites, but the river terraces contain generally more or less clay. Marsh soils are often found in deltas the result of river deposits; but for reasons already given, indigenous soils may become swampy; they are found almost in all sections, but most frequently along the Gulf and the Coast of the Atlantic; the largest in the United States are the Dismal Swamp of Virginia, and the Everglades in Florida. Brackish swamps are commonly called salt meadows. There are very few peat deposits in the United States, but they are quite frequent in Newfoundland, Great Britain, and Germany; the non malarious character of peat soils has been justly attributed by Dr. Britton to the antiseptic action of organic acids contained therein.

The *marine alluvium* forming our salt meadows, though not malarial, are objectionable, on account of their dampness and liability to overflow. A large portion of the far West is covered by alkaline plains. The soil is generally a light loam, sometimes clayey or sandy, containing very little organic matter, but an excess of sulphates, carbonates, or chlorides of soda, potash, magnesia, and lime. These salts render the waters intensely purgative and dyspeptic, and renal affections are quite common. The soils are otherwise healthy, provided no pollution has taken place; the clouds of alkaline dust are very objectionable, and catarrhal diseases and eye troubles are frequently seen. The soils predominate in Idaho, Utah, Wyoming, Nevada, Arizona, and New Mexico; the great basin or arid region formerly covered with an inland sea, and of which the great Salt Lake and a number of smaller alkaline lakes still remain. At present, this section is only sparsely settled on account of the scarcity of water; all of the arable land near the mouth of canons, and along the mountain streams, has been taken up, however. My observation in this section teaches me

that the well water is almost unfit for domestic purposes, but the springs and artesian wells furnish a supply of good quality.

The *seashore sands* are too well known for their salubrity to require further comment. Reference has already been made to the objections of so-called "*made ground*," and we need hardly repeat that deep lots should never be made the dumping-ground of waste matter and rubbish mingled with dirt, nor is it necessary to insist that a swampy place cannot be made dry by a deposit of even good soil. Whilst proper grading is very desirable in the construction of streets and the preparation of building sites, the depressions should never be filled up until they are thoroughly drained, and then only with pure soil.

Having briefly considered the general characteristics of soil which have been *transported* to their present resting-places by the forces of nature or the hand of man, reference should be made to the *indigenous* soils, so called, because they result from the disintegration of the local rock formations. These soils predominate in the non-glaciated parts of the country, where they form most of the superficial accumulations, also wherever the glacial drift is thin or wanting. A heavy deposit of this drift naturally obstructs the action of the elements upon the indigenous rock formation. To this class of soils belong those derived from granite, gneiss, trap, porphyry, and feldspathic rocks generally, yielding either stiff or loose clays or loams. A true sandy soil is rarely produced from such rocks, and they are not specially salubrious unless rendered so by perfect natural surface-drainage.

These soils are found in patches on the eastern slope of the Appalachian range, especially in Western New Jersey southward; they are generally found in hilly or mountainous regions—in certain parts of the Rocky Mountains, the Sierras, and other western ranges.

The soils derived from *slates* or *shales* are often clayey, and therefore objectionable, unless the strata are sufficiently

tilted. Such soils are freely met with along the southern and middle portions of the Appalachian range, in the Southern and Central States, and in the far West. The salubrity of *sandy soils* has already been pointed out, and this is especially the case when the sandy loams have been formed by the disintegration of the rock, and therefore less contaminated with other alluvial deposits. These soils are very common in the United States south of the glacial drift. The soils derived from indigenous limestone and marble are also quite common in this country, and have already been referred to.

[For further details, see Parke's Hygiene, American Additions, from which the foregoing has been condensed.]

Examination of the Soil.—A complete sanitary investigation should include the following points, viz :

(1) The configuration of the locality, height above the sea level, angle of declivity, facilities for natural drainage, water-sheds and courses, covering of soil by trees, brushwood, and grasses.

(2) Geological formation, dip and character of strata, especially in reference to their permeability.

(3) Examination into the size of the fragments or grains composing the soil is readily conducted by means of graduated sieves and a low power of the microscope.

(4) The porosity of the soil is usually determined by taking a liter of kiln-dried soil and ascertain how much water is taken up. The water must be added until air-bubbles cease to form. This is a simple, but not the most exact method.

(5) The *moisture* of the soil is determined by weighing a certain quantity; it is then exposed to a temperature of 220° until dry, and weighed again; the difference is water or some volatile substance.

(6) The *capacity of the soil for holding water* is ascertained by thoroughly wetting a certain quantity previously weighed, drain off the water, and weigh again. This is not a precise method.

(7) *Measurement of the Ground-Water.*—The height of the water-level in wells is the best indication of the height of the ground-water. Pettenkoffer uses a rod for shallow wells and a cord for deep wells, to which are attached a number of little cups, which are let down into the well and drawn up again; the uppermost cup containing water, marks, of course, the height of the water, the length of this measure being known, the changing level of the well can be estimated to within one-half inch. Some precautions are necessary; for if a rope is used, it may stretch after prolonged use or during a hot wind, or shrink in wet weather, and thereby render the observations inaccurate, but not sufficiently so for practical purposes. It is best to use a rod in shallow wells, and the measurement should be made at a time when the supply has not been lowered by unusual consumption.

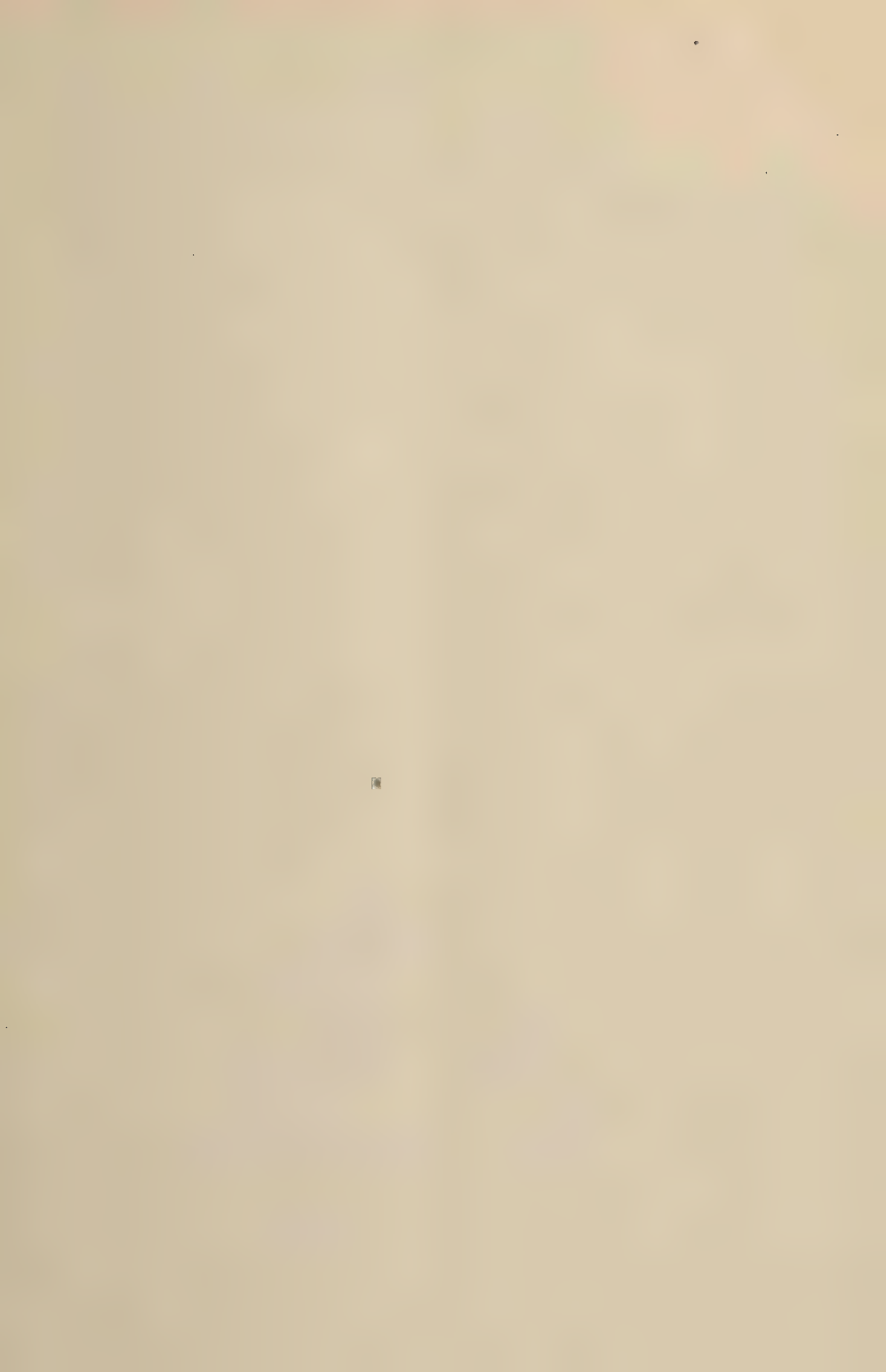
(8) *The ground air* is examined by sinking a shaft about sixteen feet deep, into which are placed lead pipes in 1½ feet, three feet, seven feet, nine feet, and fifteen feet lengths, and one-half inch in diameter. The soil is put back as nearly as possible into the original levels. The lead pipes are connected with an aspirator by means of rubber-tubing, and the aspirated air is examined for the determination of oxygen, carbonic acid, ammonia, hydrogen sulphide, and organic matter. The movements of the ground-air are determined by differential manometers.

(9) *Soil-pollution* is determined by a chemical analysis for the estimation of nitrogen and carbon. A simple way to ascertain the percentage of volatile matter is to take ten grammes of dried pulverized soil, incinerate at a red heat, recarbonate with carbonic acid solution or ammonia carbonate; heat again to expel excess of ammonia and weigh. The loss represents the amount of organic matter. The permanganate process is also applicable.

(10) The *micro-organisms* of the soil are best determined by using a borer invented by Fränkel, and constructed on the principle of a butter-tester. This borer must be steril-

ized, and can be inserted to any desired depth. Upon withdrawal of the instrument, Fränkel measures off, by means of a sterilized platinum spoon, a given quantity of the soil, and places it in a nutrient gelatine-culture tube, and shakes the mixture well. A small quantity of this is placed on glass plates under a damp glass air-chamber; and after the formation of the colonies, they are counted and isolated in the usual manner. The platinum measures hold about two grains of soil, as a larger amount would render the culture experiment very difficult and confusing because of the number of micro-organisms present.

(11) *The temperature of the soil* can be readily determined at any desired depth by placing a self-registering thermometer, properly protected, in a "drive well point joint."



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